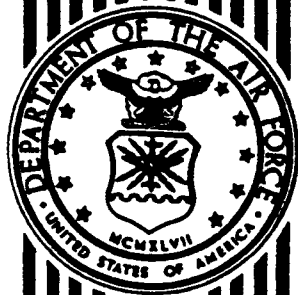


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ALTERNATIVE TRAINING AGENTS
PHASE IV - LARGE-SCALE TESTS

MICHAEL E. LEE, JONATHAN S. NIMITZ,
AND ROBERT E. TAPSCOTT

NEW MEXICO ENGINEERING RESEARCH
INSTITUTE

UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO 87131

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FINAL REPORT

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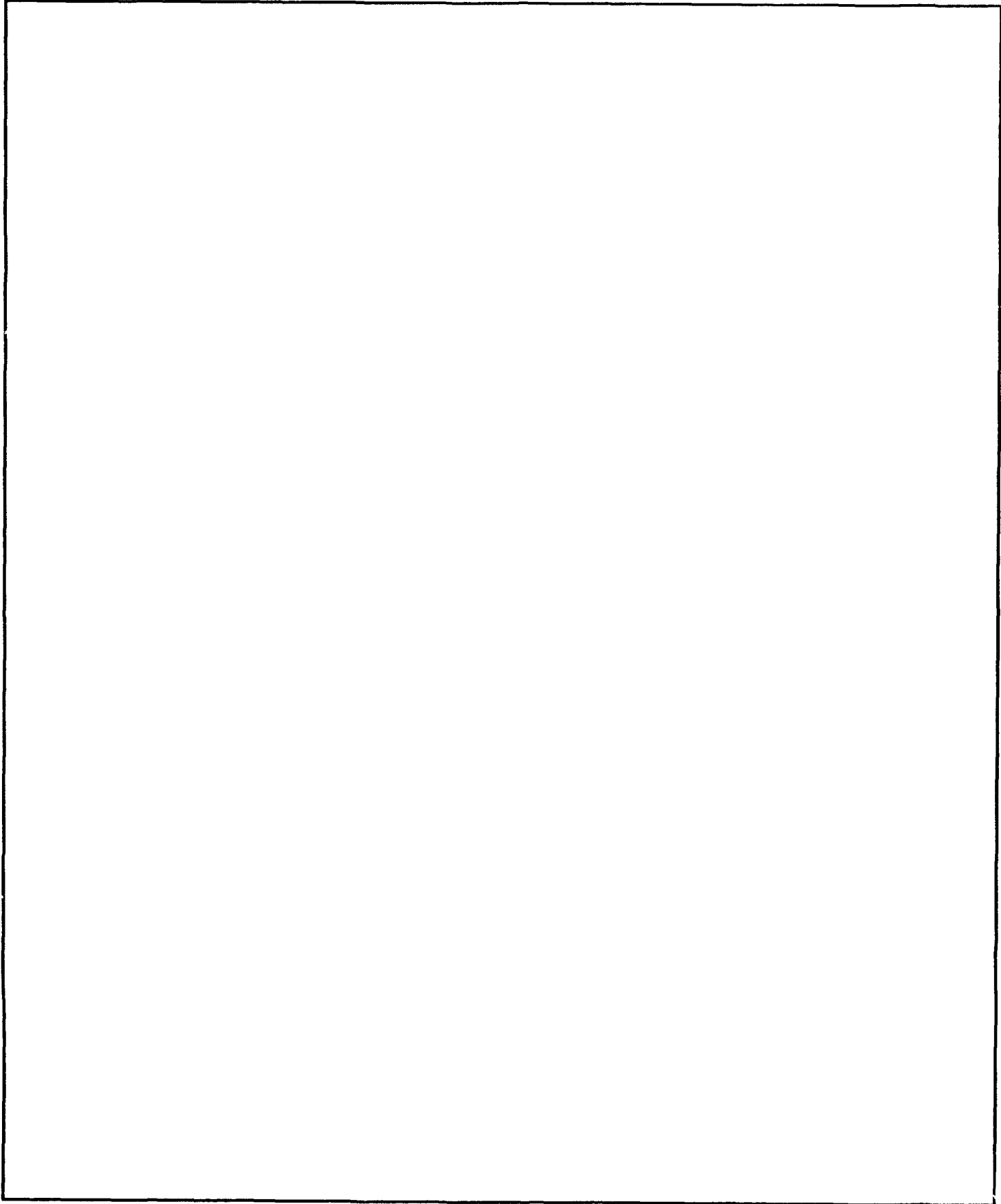
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EXECUTIVE SUMMARY

A. OBJECTIVE

The overall objective of this effort is to evaluate candidate low ozone-depleting halon alternatives for potential use in place of Halon 1211 in firefighter training scenarios.

B. BACKGROUND

In 1986, approximately 70 percent of Air Force usage of Halon 1211 was in firefighter training. Evidence from scientific studies indicates that Halon 1211 contributes significantly to the depletion of stratospheric ozone. In response to this finding and the resultant Montreal Protocol, industry will phase out production of Halon 1211 by the year 2000 for all but essential uses. In Phase I of this effort promising near-term candidate agents having low ozone depletion potentials were identified for firefighter training. These candidates included HCFC-123 in pure form and in blends with HCFC-22, -141b, or -142b. In Phase II of this effort, laboratory-scale tests were conducted on pure HCFC-123 and blends using both cup burners and the laboratory-scale discharge extinguishment (LSDE) apparatus. In Phase III, the candidate agents were further tested progressively on fires of 4-, 32-, and 75-ft³. Standard Halon 1211 extinguishers were used by experienced firefighters to determine the effectiveness of the agents when tests similar to existing training scenarios were used. Various sizes of extinguishers were used to determine the minimum agent amounts and flow rates needed to extinguish the fires. The series of tests described in this Phase IV report was a continuation of the field tests described in the Phase III report.

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C. SCOPE

This phase of testing consisted of two stages. Standard 150-ft² and three-dimensional (3-D) running fuel 75-ft² fires were used to simulate various training and realistic fire scenarios. Several candidate agents were tested in each stage.

D. METHODOLOGY

Several sizes of standard Halon 1211 extinguishers were filled to their charge capacities with the candidate agents and pressurized to various test pressures with nitrogen. These extinguishers were used to apply the agents onto the test fires with standard firefighting techniques. The extinguishers were weighed before and after each test, and each test was timed to determine the amount of agent used on the fire and the agent flow rate. The reaction of the agent and the fire when the agent was applied and the amount of difficulty in extinguishing the fire were also noted and considered in the agent evaluation.

In addition to the standard fires, a running fuel, semi-3-D apparatus was constructed and tested in conjunction with the 75-ft² pan fire. A survey of several different types of 3-D training apparatuses was conducted throughout the Department of Defense, industry, and research institutions. No standard training apparatus was found. Several types of apparatus were considered, and two were fabricated and tested. These apparatuses were designed to simulate a suspended jet engine fire with a fuel line leak within the engine. In this scenario, an engine mounted underneath a wing of the aircraft spills fuel onto the runway.

E. TEST DESCRIPTION

In this phase of testing, three apparatus configurations were used to test the effectiveness of various agent blends. Both a prototype and a final design 3-D running

fuel apparatus were used in conjunction with a 75-ft² fire pan or containment ring. A 150-ft² fire pit was used for the final testing evaluation. Standard 150-pound Halon 1211 extinguishers were filled with Halon 1211 or mixtures of HCFC-123 with either HCFC-22 or HCFC-142b and used in this testing.

F. RESULTS

It was found that both neat HCFC-123 and an 80:20 blend (by moles) of HCFC-123 and -142b simulated Halon 1211 in training scenarios; these agents were designated OPE-1 and OPE-2, respectively, standing for Ozone Protective Extinguishants numbers 1 and 2.

By using information from appropriate personnel involved in firefighter training, a realistic training scenario was established and the apparatus was accordingly designed to satisfy these training requirements.

G. CONCLUSIONS

Both OPE-1 and OPE-2 are effective extinguishing agents that can simulate Halon 1211. A nozzle change is required for effective extinguishment and simulation of Halon 1211. OPE-2 is approximately 20 percent less toxic than OPE-1, but is also a slightly less effective extinguishant. Approximately 20 percent more OPE-2 than OPE-1 is required to extinguish comparable fires. The logistics of handling a neat agent such as OPE-1 would also be simpler than that for handling a blend such as OPE-2.

H. RECOMMENDATIONS

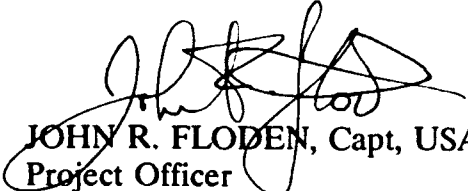
It is recommended that either OPE-1 (neat HCFC-123) or OPE-2 (an 80:20 blend by moles of HCFC-123 and -142b) with a nozzle change be used for firefighter training.

PREFACE


This report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, Albuquerque, New Mexico 87131-1376, under contract F08635-85-C-0129, for the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida 32403-6001.

This report summarizes work accomplished at NMERI between 1989 and November 1990. The HQ AFESC/RDCF Project Officer was Capt. John Floden. Robert E. Tapscott was the principal investigator. Jimmy D. Watson and Jesse M. Parra were the project technicians for the testing portions of this work.


This report has been reviewed by the Public Affairs Officer (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.




JOHN R. FLODEN, Capt, USAF
Project Officer



NEIL H. FRAVEL, Lt Col, USAF
Chief, Engineering Research Division



L. M. WOMACK
Chief, Air Base Fire Protection
and Crash Rescue Systems Branch



FRANK P. GALLAGHER, Col, USAF
Director, Engineering and Services
Laboratory

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LIST OF ABBREVIATIONS

CERF	Civil Engineering Research Facility
HCFC	hydrochlorofluorocarbon
ID	inside diameter
LSDE	laboratory-scale discharge extinguishment
MSDS	Material Safety Data Sheet
NMERI	New Mexico Engineering Research Institute
OD	outside diameter
OPE	Ozone Protective Extinguishant
SCBA	self-contained breathing apparatus
TFT	Task Force Tip, Inc.
3-D	three-dimensional

SECTION I

INTRODUCTION

A. OBJECTIVE

The overall objective of this effort is to evaluate candidate halon alternatives for potential use in place of Halon 1211 in firefighter training scenarios. The purpose of this phase was to test four candidate agents (neat HCFC-123 and blends of 80:20 or 70:30 by moles HCFC-123 and -142b, and 80:20 HCFC-123 and -22) on 75-ft² three-dimensional (3-D) and 150-ft² pool fires.

B. BACKGROUND

Approximately 70 percent of Air Force usage of Halon 1211 is in firefighter training. Evidence from scientific studies indicates that Halon 1211 contributes significantly to the depletion of stratospheric ozone. In response to this finding and the resultant Montreal Protocol, industry will phase out production of Halon 1211 by the year 2000 for all but essential uses. In Phase I of this effort promising near-term candidate agents having low ozone depletion potentials for firefighter training were identified (Reference 1). These candidates included HCFC-123 in pure form and in blends with HCFC-22, -141b, or -142b. In Phase 2 of this effort laboratory-scale tests were conducted on pure HCFC-123 and blends using both cup burners and the laboratory-scale discharge extinguishment (LSDE) apparatus (Reference 2). In Phase 3, the candidate agents were further tested progressively on fires of 4, 32 and 75 ft². Standard Halon 1211 extinguishers were used by experienced firefighters to determine the effectiveness of the agents when tests similar to existing training scenarios were used (Reference 3). Various sizes of extinguishers were used to determine the minimum agent amounts and flow rates needed to extinguish the fires. The series of tests described in this Phase IV report was a continuation of the field tests on 4-ft² through 75-ft² fires described in the Phase III report.

C. SCOPE

This phase of testing consisted of two stages. Standard 150-ft² and 3-D running fuel 75-ft² fires were used to simulate various training and realistic fire scenarios. Several candidate agents were tested in each stage.

D. TECHNICAL APPROACH

Several sizes of standard Halon 1211 extinguishers were filled to their charge capacities with the candidate agents and pressurized to various test pressures with nitrogen. These extinguishers were used to apply the agents onto the test fires with standard firefighting techniques. The extinguishers were weighed before and after each test, and each test was timed to determine the amount of agent used on the fire and the agent flow rate. The reaction of the agent and the fire when the agent was applied and the difficulty in extinguishing the fire were also noted and considered in the agent evaluation.

In addition to the standard fires, a running fuel, semi-3-D apparatus was constructed and tested in conjunction with the 75-ft² pan fire. A survey of several different types of 3-D training apparatuses was conducted throughout the Department of Defense, industry, and research institutions. No standard training apparatus was found. Several types of apparatuses were considered, and two were fabricated and tested. These apparatuses were designed to simulate a suspended jet engine fire with a fuel line leak within the engine. In this scenario, the engine would be mounted underneath the wing of the aircraft and the fuel would be spilling out of the engine onto the runway.

SECTION II TEST EQUIPMENT AND FACILITIES

A. TEST FACILITIES

The testing facilities were located on Kirtland Air Force Base at the Civil Engineering Research Facility (CERF). The tests were conducted in a fenced wind enclosure constructed of TENAX Riparella mono-oriented net wind fencing. The wind enclosure was constructed as a pair of concentric circles to maximize the wind abatement effect.

The enclosure totally surrounded the test area and had an outer fence diameter of 140 ft, an inner fence diameter of 85 feet, and a height of 20 feet. The 75-ft² pan and 150-ft² pit were located within this structure.

The first series of 75-ft² 3-D running fuel fires was conducted in a square 75-ft² fire pan. The pan was constructed of 0.25-inch thick steel with a 1.25-inch steel angle welded along the top outside edges of the pan. The pan had dimensions of 8 feet, 8 inches (square) by 8 inches deep. The edges of the pan were bermed with earth to minimize turbulence caused by air entrainment during fire testing. The first 3-D fire apparatus was placed in this pan.

The first 3-D apparatus (Figure 1) was fabricated of 25 inches steel pipe. The pipe was cut to 3.5 feet in length and was mounted on four legs at a 10-degree slope. The front lip of the apparatus was raised 3.5 to 4 feet above the top edge of the fire pan by the leg structure; the back end of the pipe was raised 10 degrees. The apparatus was placed halfway in the fire pan with the raised end out of the pan. A 1-inch black, steel pipe fuel line was connected from a fuel tank, through an electric metering pump and a flash arrestor valve, to a horizontal spray bar that distributed the fuel evenly into the

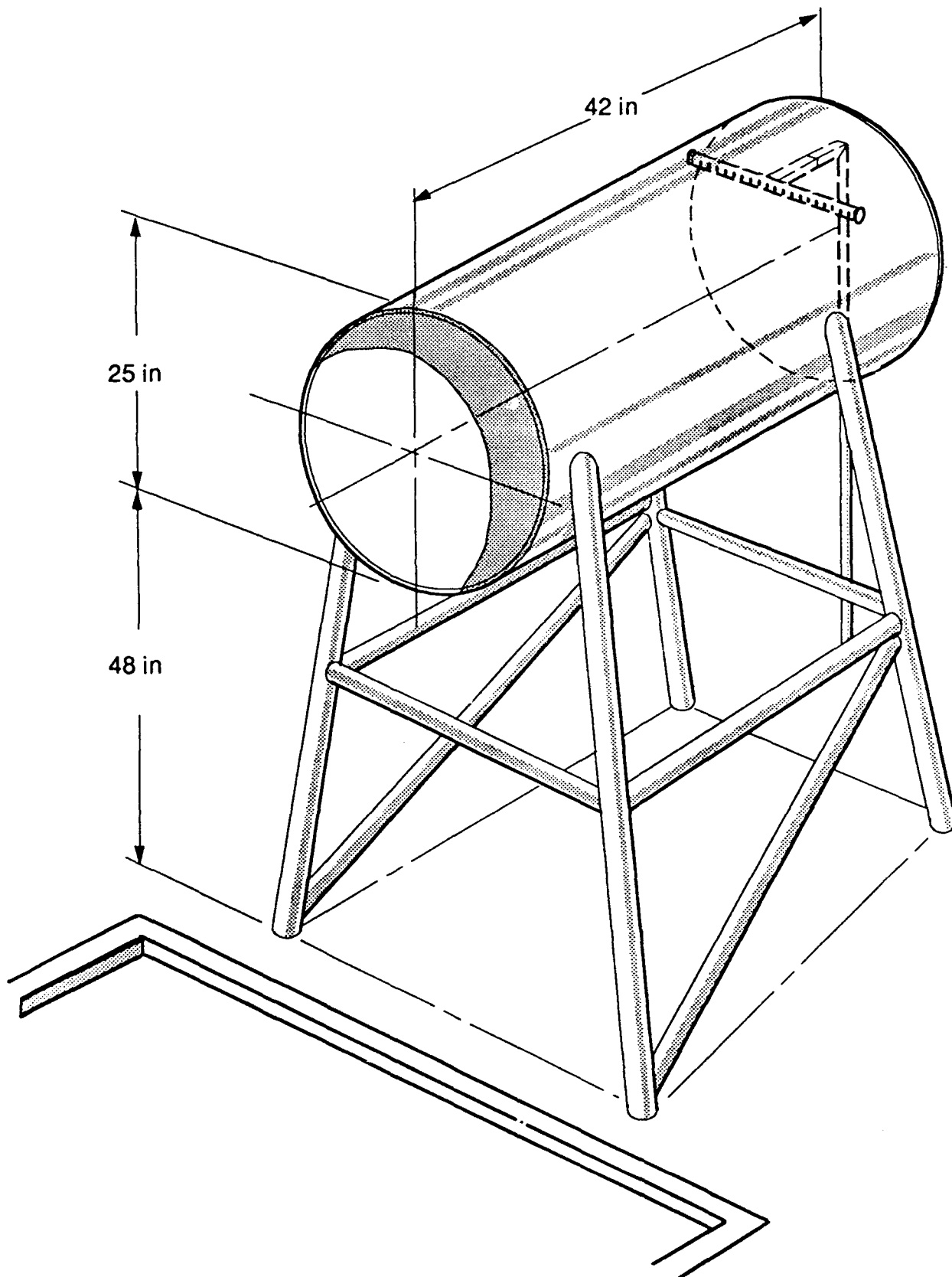


Figure 1. Prototype Running Fuel (3-D) Apparatus.

rear of the 25-inch pipe. After the fuel was sprayed into the pipe, it was allowed to flow through the pipe and into the fire pan to create a running 3-D fire. The fuel flow through this apparatus was controlled at 15 to 20 gallons/minute by a 1-inch gate valve in the fuel line.

The second 3-D apparatus (Figures 2 and 3) was constructed of two barrels and one intake port of a B-52 aircraft engine cowling. The barrels were nested one inside the other with strut supports welded to the barrels to keep the inner barrel equidistant from the inner edge of the outer barrel. The inner barrel was a standard 55-gallon drum with a diameter of 22.5 inches and a length of 36 inches. The outer drum was an overpack drum with a diameter of 30 to 36 inches and a length of 44 inches. The drums were hung from a fabricated swivel mount on a horizontal boom so that the front edges of the barrels were 15 degrees lower than the back edges. The engine cowling was mounted over the front edge of the outer barrel. A flexible fuel line was run along the boom and into a vertically mounted multidirectional spray bar that was shielded so that the fuel was sprayed toward the front, or lower end, of the apparatus. The fuel sprayed into the inner barrel, and a portion of the fuel flowed into the outer barrel through circular holes cut into the bottom of the inner barrel. The remainder of the fuel flowed the length of the inner barrel, and into the overlapped edge of the outer barrel. The fuel was then guided out the outer edge of the cowling, allowing some fuel to enter the inside of the cowling, and from there allowed to flow into the circular containment pit located 4 to 5 feet below the apparatus. Fuel flow was regulated at 3.5 gallons/minute through a gate and ball valve arrangement. The circular fire pit below the suspended apparatus was filled with water. A circular metal ring, 16 inches tall, was placed in the center of the pit to contain the fuel to a 75-ft² area.

The 150-ft² tests were conducted in a circular fire pit, 14 feet 8 inches in diameter and 16 inches deep. The pit was filled with water until a 2-inch vertical freeboard space was reached. The fuel was then pumped into the pit in 12- or 25-gallon quantities.

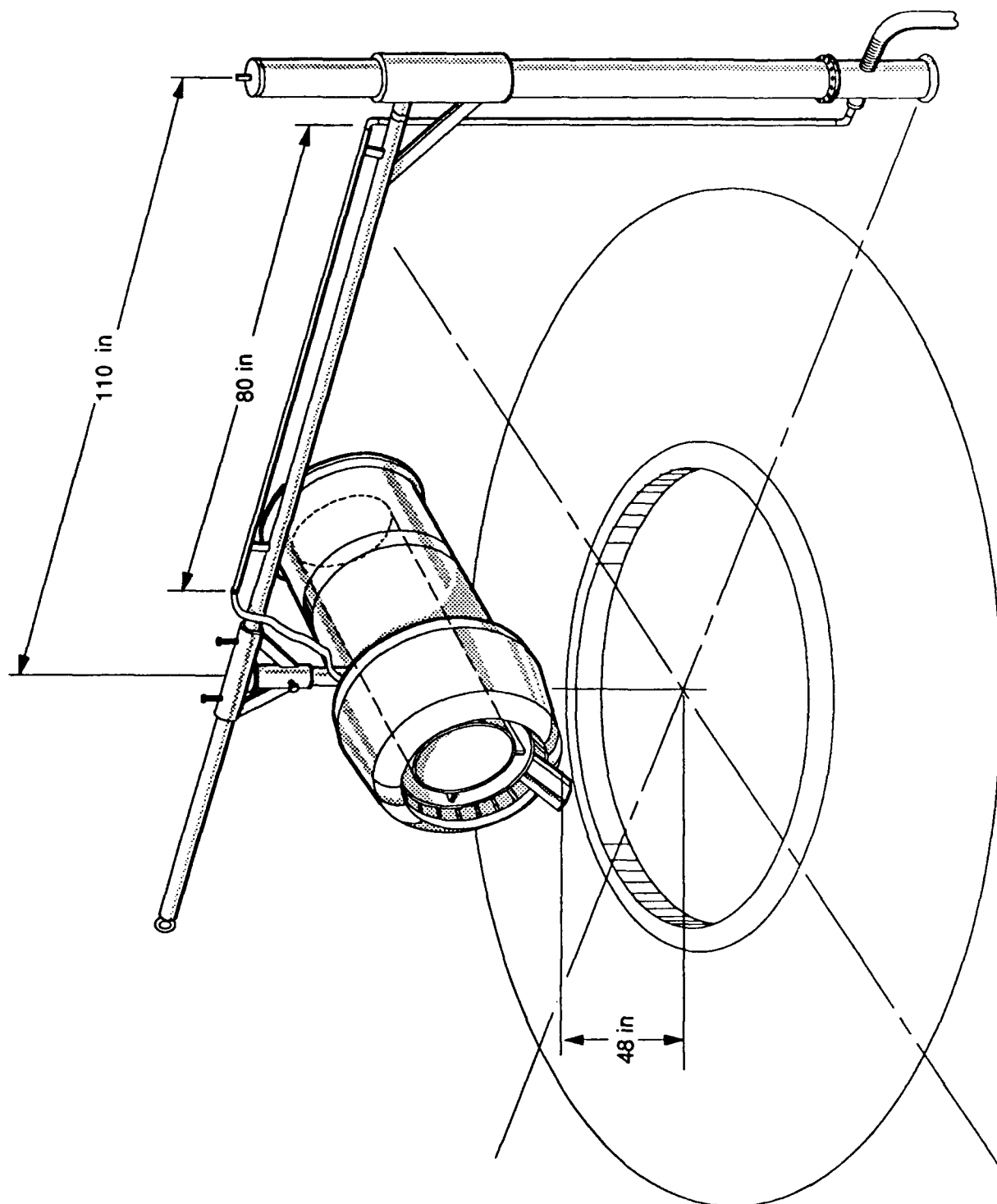


Figure 2. Final Running Fuel (3-D) Apparatus.

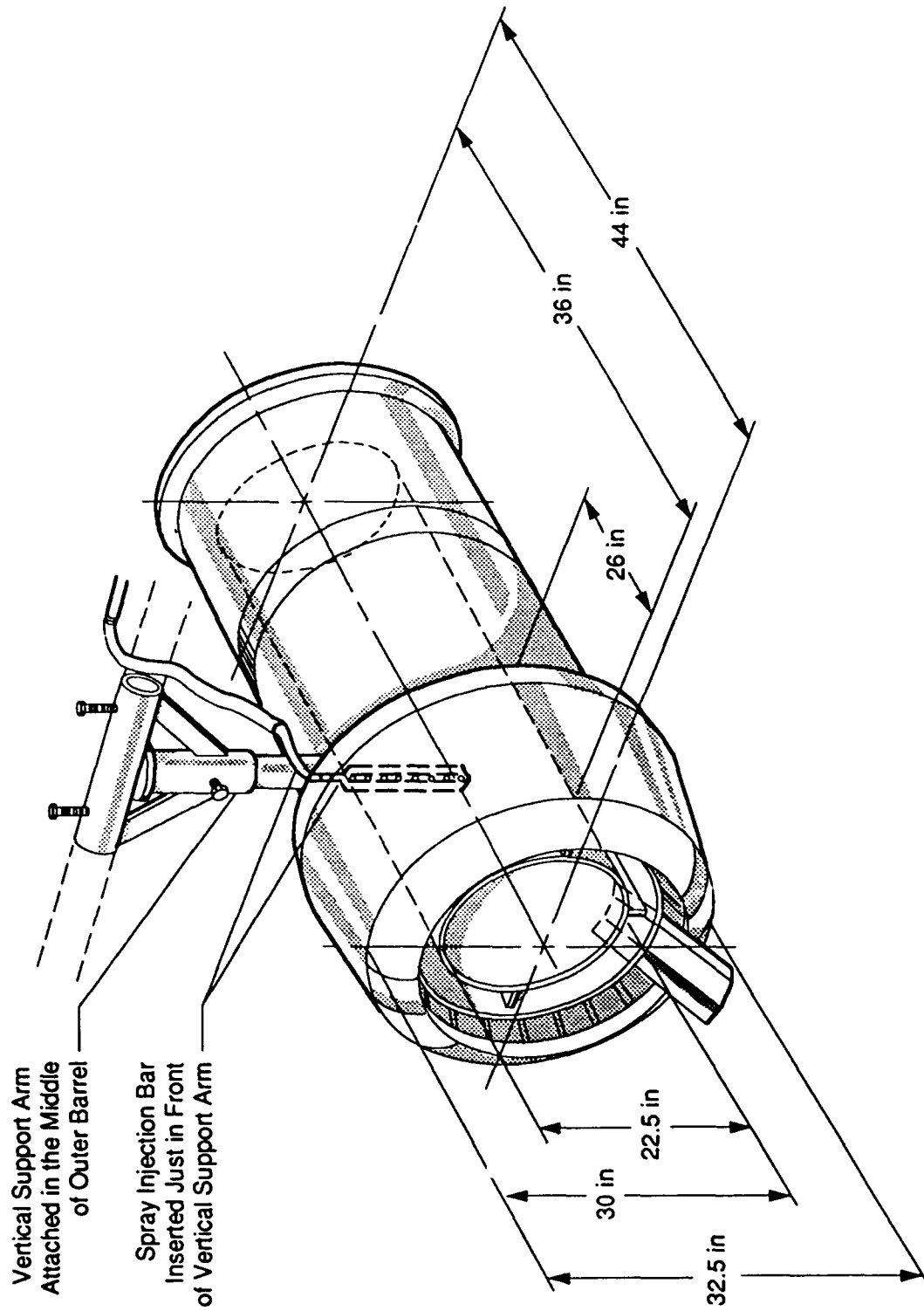


Figure 3. Expanded View of Engine Cowling in Final Running Fuel (3-D) Apparatus.

Military grade JP-4 was used as the combustion fuel for all tests. In the first tests, the 75-ft² pan was used in conjunction with the first 3-D apparatus. The fuel flowed through the apparatus and filled the 75-ft² pan before the fuel was ignited. Ten to twenty-five gallons of fuel were used for each test. In the second series of 3-D tests, fuel flowed through the apparatus into the lower containment ring. Five to ten gallons of fuel were used in each of these tests. Both 12- and 25-gallon volumes of fuel were tested with the 150-ft² fire. These volumes gave 0.25 to 0.375 inches of fuel above the water surface.

Standard Amerex fightline 150-pound Halon 1211 extinguishers were used for all tests. Hand-held 20-pound extinguishers were initially tested on the 3-D fires and did not provide sufficient agent to control or extinguish the fire. Standard, smooth-bore nozzles connected to the extinguishers with 0.75-inch diameter, 50-foot lengths of hose were tested. These delivered the agents with a concentrated straight stream that did not provide adequate knockdown and allowed burnback. Tests with adjustable, fogging nozzles were much more successful.

B. PROCEDURES

In the initial tests, the first 3-D apparatus was placed in the 75 ft² pan. The standard 150-pound flightline extinguishers fitted with standard, smooth-bore nozzles were used for these tests. It was found that the fire was too intense to control effectively if the full fuel amount of 25 gallons was added to the pan before the test. Therefore, the fuel was allowed to flow through the apparatus into the pan and just cover the surface of the water in the pan before it was ignited. The bottom pan was allowed to become fully engulfed in flame before extinguishment was started, usually requiring a 30-second preburn period. The firefighter extinguished this fire by building up a large concentration of agent in the lower pan using a sweeping motion similar to the methods used in earlier tests. Once most of the fire in the bottom pan had been controlled, the agent stream was directed into the apparatus and the running fuel fire was extinguished.

The firefighter then completed extinguishment of the bottom fire and any remaining fire in the apparatus.

The second 3-D apparatus was suspended above a pool of water containing a 75-ft² fuel containment ring. Fuel was allowed to pour through the apparatus into the containment ring at a set rate of 3.5 gallons/minute. Once the fuel covered most of the water surface in the ring, the fuel was ignited. A minimal preburn of 10 to 20 seconds was allowed for this test. Both the standard flightline nozzle and adjustable, fine spray nozzles were attached to 150-pound extinguishers for these tests. The fine spray nozzles included the Task Force Tip, Inc. (TFT) nozzle and Akron Brass Models 1701 and 4507. The firefighter contained and largely extinguished the bottom fire, then directed the agent stream to the upper apparatus fire. If any fire remained, it was then quickly extinguished. The TFT fine spray nozzle produced an agent pattern that was more comparable to Halon 1211 and, if properly used, rapidly extinguished this type of fire.

In the 150-ft² tests, the fuel was pumped into the pit on top of the water after the pit and water had been cooled from previous testing. The test area is shown in Figure 4. The fuel was ignited and allowed to burn for 30 seconds before the agent was applied. The firefighter approached the fire from the upwind direction and swept the agent stream in front of the pit to build up the agent concentration, then moved the stream into the pit. Once initial knockdown of the fire was accomplished, the firefighter swept the agent stream briskly side-to-side, overlapping the sides of the pit to prevent flashback from the fire. The fire was then worked to the back of the pit where any remaining flames were extinguished. All nozzles were used in these tests, and it was determined that the TFT nozzle, with the agent pressurized to 260 lb/in.², was the best for the candidate agents. A standard, smooth-bore nozzle was used for the Halon 1211.

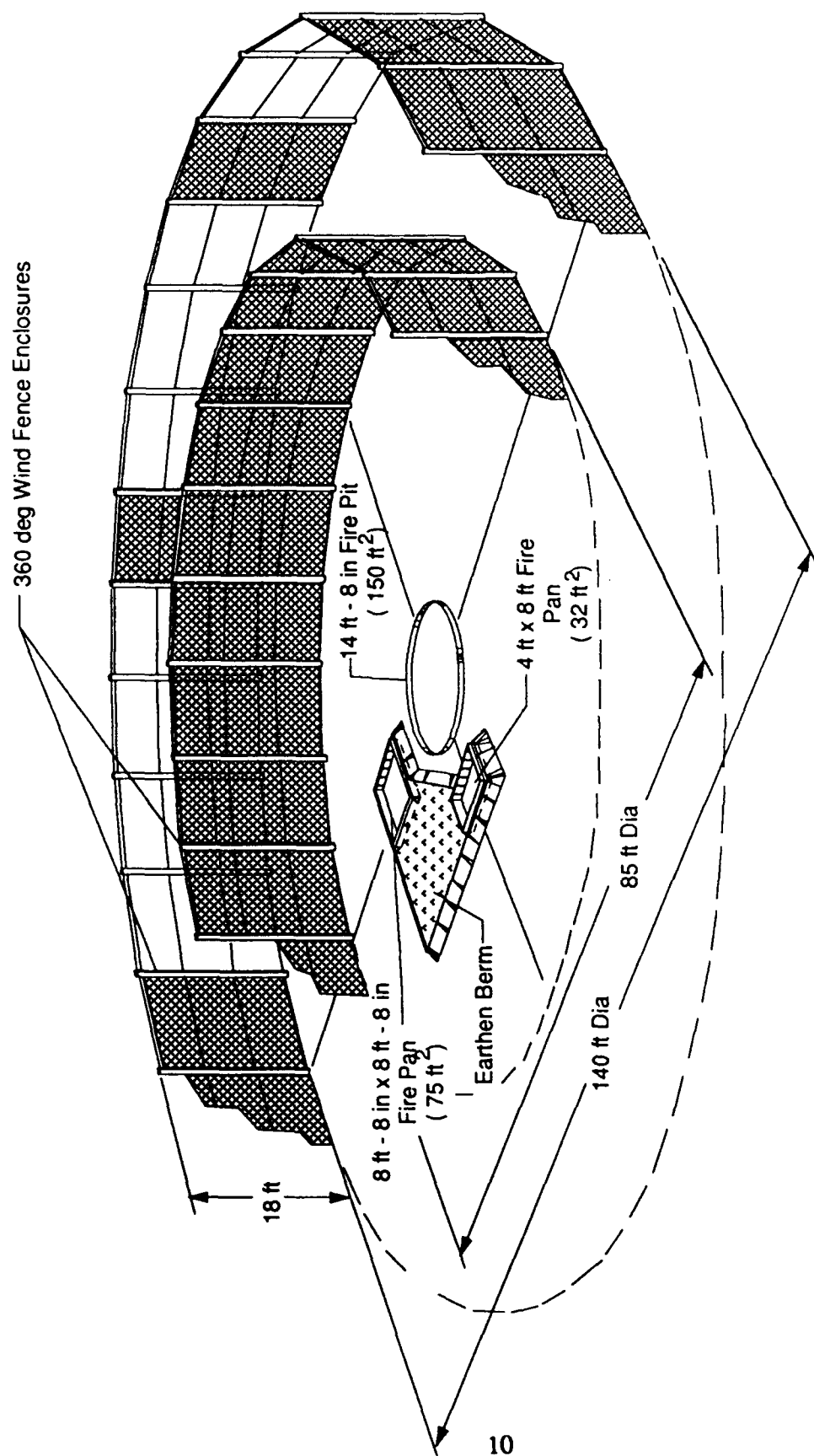


Figure 4. Primary Test Area and Wind Fence Enclosure. (All fencing panels are in place in the actual wind fence enclosures.)

SECTION III RESULTS

A. GENERAL

In this phase of testing, three apparatus configurations were used to test the effectiveness of various agent blends. Both a prototype and a final design 3-D running fuel apparatus were used in conjunction with a 75-ft² fire pan or containment ring. A 150-ft² fire pit was used for the final testing evaluation. Standard 150-pound Halon 1211 extinguishers were filled with Halon 1211, and with the mixtures of HCFC-123, HCFC-22, and HCFC-142b used in this testing.

This phase of the testing was modified to include testing with a 3-D fire test apparatus in order to test the candidate agents with all currently available standard training scenarios. Air Force installations and fire industry/test and training laboratories were contacted to determine whether a standard 3-D test apparatus was being used. It was found that there was no standard apparatus or training scenario. Therefore, the prototype apparatus was designed, incorporating recommendations from personnel and fire training officials contacted. By using this information, a realistic training scenario was established, and the apparatus was designed to meet these training requirements.

B. PROTOTYPE TESTING

In the first series of tests, the prototype apparatus was set up to simulate a running, semi-3-D fuel training fire. This apparatus was fabricated of steel pipe, 25 inches in diameter and 3.5 feet long, mounted on four legs at a 10-degree slope. The apparatus was placed halfway in the fire pan with the raised end out of the pan and the lowered end raised 3.5 to 4 feet above the square 75-ft² fire pan. Fuel was pumped at a constant rate of 15 to 20 gallons/minute through a horizontal spray bar that distributed

the fuel evenly into the rear of the 25-inch pipe. After the fuel was sprayed into the pipe, it was allowed to flow through the pipe and into the fire pan, creating a simulated running fuel 3-D fire.

Since this fire was expected to be quite difficult to control and extinguish and no standard method of firefighting could be found for this type of training scenario, Halon 2402 was chosen as an apparatus test agent. The use of this very effective outdoor extinguishing agent was limited to preliminary tests that allowed the firefighter to establish an effective extinguishing method that could be used safely in later testing. Five tests were conducted in which an average of 32 pounds of Halon 2402, at a flow rate of 1.7 lb/s, was required to extinguish the fire. The 150-pound extinguishers with the standard flightline, smooth-bore nozzle and 0.75-inch hose were used for these tests. It was found that this agent extinguished the fire 60 percent of the time; however, the most effective extinguishing techniques were still being developed and if further testing with this agent had continued, this effectiveness could have increased.

The next agent to be tested was Halon 1211. Various extinguishing methods were suggested by training personnel, and these methods were tested at this time. The most effective method extinguished this fire by building up a large concentration of agent in the lower pan using a sweeping motion similar to the methods used in earlier tests. Once most of the fire in the bottom pan had been controlled, the agent stream was directed into the apparatus and the running fuel fire was extinguished. The firefighter then finished extinguishing the bottom fire and any remaining fire in the apparatus. Seventeen tests were conducted with Halon 1211, and the fire was extinguished 47 percent of the time. In these tests, an average of 75 lbs of Halon 1211 and a flow rate of 2.9 lb/s were used to extinguish the fire.

Two candidate alternative agents were also tested with this apparatus: neat HCFC-123 and HCFC-123 & HCFC-22 (80:20).^{*} One test of each agent was conducted that neither extinguished nor controlled the fire. Testing with this apparatus was finalized, and the new apparatus was designed and constructed. The results obtained with the first 3-D apparatus are summarized in Table 1.

C. FINAL APPARATUS TESTING

The prototype testing was used to develop the final 3-D test apparatus, test procedure, and firefighting techniques. The final apparatus was designed to simulate an aircraft engine attached under the wing of an aircraft in which a broken fuel line was spewing fuel from the engine onto the runway. Although this fire was not as intense as the prototype fire, it produced a more realistic test fire and one that much more closely resembled training scenarios. This apparatus was constructed using two barrels and an intake port of a B-52 aircraft engine cowling. The barrels were nested one inside the other with strut supports welded to the barrels to keep the inner barrel equidistant from the inner edge of the outer barrel. The inner barrel was 22.5 inches in diameter and 36 inches long. The outer drum was 30 to 36 inches in diameter and 44 inches long. The drums were hung from a fabricated swivel mount on a horizontal boom so that the front edges of the barrels were 15 degrees lower than the back edge. The engine cowling was mounted over the front edge of the outer barrel. A fuel line was attached to a multidirectional spray bar, which was shielded so that the fuel was sprayed toward the front (lower end), of the apparatus. The sprayed fuel flowed through the apparatus and into the circular pit located 4 to 5 feet below the apparatus. The ring in this pit contained the fuel to a 75-ft² area. Fuel flow was regulated at 3.5 gallons/minute.

^{*}All blend ratios or percents are by moles.

TABLE 1. DATA FOR 75-FT² 3-D FIRES (PROTOTYPE APPARATUS).

Agent	Mole Percent	Total Tests	% Eff.	Extinguishment Test Averages			Nonextinguishment Test Averages		
				Agent Wt., lbs	Time to Ext., s	Agent Flow Rate, lb/s	Agent Wt., lbs	Time to Ext., s	Agent Flow Rate, lb/s
Halon 2402	100	5	60	32	18.8	1.7	89.3	58.7	1.7
Halon 1211	100	17	47	74.6	29.7	2.8	131.4	67.5	2.0
HCFC 123	100	1	0	a	a	a	106.0	69.7	1.5
HCFC-123 & -22	80:20	1	0	a	a	a	116.0	66.2	1.8

^aNot applicable.

Tests were conducted with Halon 1211, neat HCFC-123, and HCFC-123 and HCFC-22 (80:20). The 150-pound extinguishers were again used for this testing with both the standard flightline nozzle and adjustable, fine spray nozzles. The fine spray nozzles included the TFT nozzle and Akron Brass Models 1701 and 4507. The TFT nozzle worked best for the candidate agents and produced an agent stream similar to the flow of Halon 1211 from a standard flightline nozzle.

The results of testing using the second 3-D apparatus are given in Table 2. All fires were extinguished.

Six tests were conducted with Halon 1211, and these fires were quickly controlled and extinguished. An average of 32.2 pounds of the agents effectively extinguished the fires at a flow rate of 3.1 lb/s. The same basic firefighting method developed in the prototype testing was used and improved upon in these tests.

TABLE 2. DATA FOR 75-FT² 3-D FIRES (FINAL APPARATUS).

Agent	Mole Percent	Total Tests	% Eff.	Extinguishment Test Averages		
				Agent Wt., lbs	Time to Ext., s	Agent Flow Rate, lb/s
Halon 1211	100	6	100	32.3	7.4	3.9
HCFC 123	100	7	100	64.0	14.1	4.6
HCFC-123 & -142b	80:20	1	100	60.0	10.8	5.5

Neat HCFC-123 was also tested with this apparatus. The TFT nozzle was used at a setting that diffused the flow of the agent, effectively simulating the flow pattern and effectiveness of Halon 1211. Also, due to the flow rate restrictions of the nozzle, the extinguisher was pressurized to 260 lb/in.² to maintain a flow rate within the range of the nozzle. Seven tests were conducted, and all were successful. The fires were extinguished with an average of 64 pounds of HCFC-123 at a flow rate of 4.6 lb/s.

The candidate agent mixture HCFC-123 & HCFC-142b (80:20) was also tested with similar results. In the single test that was conducted, the fire was extinguished with 60 pounds of agent at a flow rate of 5.5 lb/s. The TFT nozzle was used for this test. More testing will be required to define completely the effectiveness of the agent with this type of fire.

D. 150-FT² TESTS

The 150-ft² tests were conducted in a circular fire pit, 14 feet 8 inches in diameter and 16 inches deep. The pit was filled with water until a 2 inches vertical freeboard space was reached. The fuel was then pumped into the pit in 12- or 25-gallon quantities, ignited, and allowed to preburn for 30 seconds. The 150-pound extinguishers were used for this testing, and both the standard flightline and TFT nozzles were used. Halon 1211, HCFC-123, and mixtures of HCFC-123 with HCFC-142b were the testing agents.

Three fires were conducted with Halon 1211, which was effective in extinguishing the fire 66 percent of the time. This low effectiveness was caused partially by the firefighting technique adjustments that had to be made to extinguish this larger fire. Once these techniques were established, the firefighter could extinguish the fire with an average of 53 pounds of Halon 1211 at a flow rate of 3.5 lb/s. The standard flightline nozzle was used for these tests.

The neat HCFC-123 was tested in seven tests with a TFT nozzle and was 71 percent effective. Slight adjustments to the nozzle were made to determine the most effective flow/spray pattern setting. Once the setting was determined, the HCFC-123 was very effective in simulating Halon 1211 in the appearance of the agent stream and extinguishment. The amount of agent required to extinguish the fire was 22 percent higher than Halon 1211 when the agent was applied at a slightly higher flow rate. The effective extinguishing amount of HCFC-123 for this size of fire was 67.6 pounds at a flow rate of 4.1 lb/s.

Two mixtures of HCFC-123 and HCFC-142b were tested, and the TFT nozzle was used for both of them. Two tests were conducted with HCFC-123 & HCFC-142b (70:30), and neither was successful in extinguishing a fire. The mixture contained too much of the flammable HCFC-142b, and the fire consistently flared up when the agent was applied, becoming difficult to control. The fire still intensified slightly when the blend of HCFC-123 & HCFC-142b (80:20) was used but could be extinguished half of the time. The fire could be extinguished with an average of 86 pounds of agent, 38 percent more than Halon 1211, at a flow rate of 5.0 lb/s. The results of 150-ft² pool fire tests are given in Table 3.

E. FINAL RESULTS

The tests demonstrated the various characteristics of the candidate agents when used in a variety of training scenarios. Neat HCFC-123 was the most effective candidate agent tested in all the tests that were conducted. In order to extinguish the 3-D fire effectively, 22 to 50 percent more of this agent had to be applied than Halon 1211 and a slightly higher flow rate was required. The mixture of HCFC-123 & HCFC-142b (80:20) was less effective than the neat HCFC-123 and tended to intensify the fire when it was applied. This intensification was readily seen with the 150-ft² tests. Compared to Halon 1211 an average increase of 38 to 47 percent of applied agent was necessary to extinguish the fires when applied at a 30 to 45 percent higher flow rate.

TABLE 3. DATA FOR 150-FT² FIRES.

Agent	Mole Percent	Total Tests	% Eff.	Extinguishment Test Averages			Nonextinguishment Test Averages		
				Agent Wt., lbs	Time to Ext., s	Agent Flow Rate, lb/s	Agent Wt., lbs	Timed Ext., s	Agent Flow Rate, lb/s
Halon 1211	100	3	66	53.0	15.5	3.5	111.5	40.2	2.8
HCFC 123	100	7	71	67.0	18.9	4.1	91.3	31.0	2.9
HCFC-123 & -142b	80:20	4	50	86.0	17.5	5.0	105.0	34.4	3.1
HCFC-123 & -142b	70:30	2	0	a	a	a	98.5	43.0	2.8

18^a Not applicable.

The prototype semi-3-D tests were useful in determining the design of the final apparatus, which could be used as a standard for further testing or firefighter training in the future. It was also shown that 32 to 50 percent more agent was necessary to extinguish the final 3-D 75-ft² fire than the standard one-dimensional fire of the same size. Firefighting techniques had to be modified, the agent flow rates had to be increased 15 to 58 percent, and new, fine spray nozzles had to be used in order to be effective against the 3-D fire.

When compared to the Phase III data, the 150-ft² test data increased linearly from the 32-ft² and 75-ft² data for required amount of agent and agent flow rate (Figure 5). This relationship is important and can be used to estimate the amount of agent or agent flow rate that will be necessary to extinguish a certain size fire.

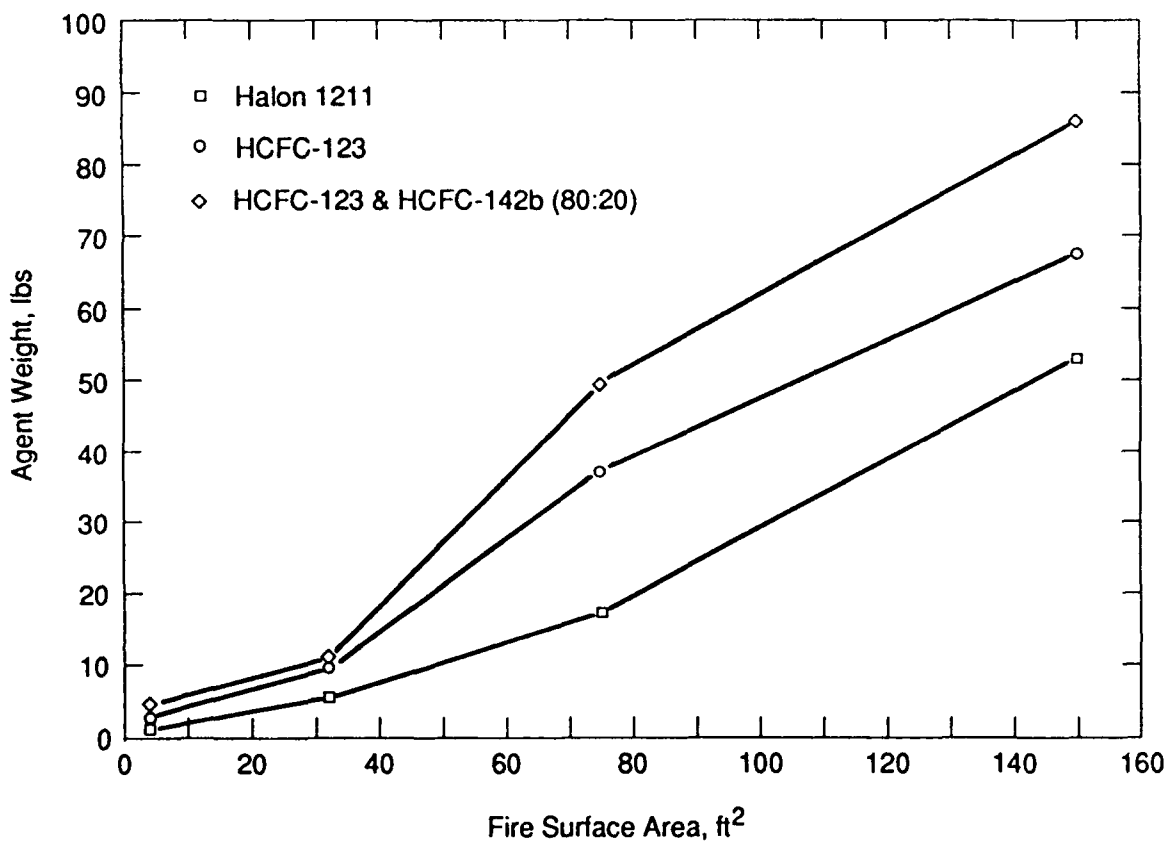


Figure 5. Agent Weight for Extinguishment Versus Fire Surface Area.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

Four candidate agents and Halon 1211 were tested using three test configurations. Neat HCFC-123, HCFC-123 & HCFC-142b (80:20), HCFC-123 & HCFC-142b (70:30), and HCFC-123 & HCFC-22 (80:20) were all tested and compared to Halon 1211. A prototype and a final design running fuel, semi-3-D fire apparatus and a 150-ft² fire pit were used in the testing. Agent application rates, spray patterns, extinguishment characteristics, and effectiveness were compared, and methods of extinguishment were established.

The two candidate agents that showed the best results were neat HCFC-123 and HCFC-123 & HCFC-142b (80:20). These agents were most effective when the TFT variable spray nozzle was used. This nozzle dispersed the flow pattern of these agents, making the flow more representative of that of Halon 1211. Neat HCFC-123 was the most effective candidate agent tested in all the tests that were conducted. In these fire tests, 22 to 50 percent more of this agent had to be applied than Halon 1211 to be effective. The mixture of HCFC-123 & HCFC-142b (80:20) was slightly less effective than the neat HCFC-123 and tended to intensify the fire when it was applied. An average increase of 38 to 47 percent of applied agent was necessary to extinguish the fires when applied at a 30 to 45 percent higher flow rate than Halon 1211.

The final 3-D, running fuel fire effectively simulated a training scenario that can be used in Air Force fire training programs. This apparatus, and the associated firefighting techniques developed, should be studied further and considered as a standard test and training scenario.

A nozzle study should be conducted to develop an inexpensive nonadjustable nozzle that can simulate the flow of Halon 1211. The TFT nozzle is not designed for use with chemical agents and is more complex than required for training.

A standard firefighting training program should be developed in which standard tests, apparatus, and techniques are used and taught. There are no guidelines for standard firefighter training scenarios within the Air Force at this time.

REFERENCES

1. J. S. Nimitz, R. E. Tapscott, S. R. Skaggs, and H. D. Beeson, Alternative Training Agents Phase I -- Survey of Near-Term Candidate Fire-Extinguishing Agents and Predicting Properties of Halocarbon Mixtures, ESL-TR-90-39, Vol. 1 of 4, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, April 1990.
2. T. A. Moore, J. P. Moore, J. S. Nimitz, M. E. Lee, H. D. Beeson, and R. E. Tapscott, Alternative Training Agents Phase II -- Laboratory-Scale Experimental Work, ESL-TR-90-39, Vol. 2 of 4, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, August 1990. (Draft)
3. M. E. Lee, J. S. Nimitz, T. A. Moore, and R. E. Tapscott, Alternative Training Agents, Phase III -- Field-Scale Tests on 4 Ft² through 75 Ft² Fires, ESL-TR-90-39, Vol. 3 of 4, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, September 1990. (Draft)

APPENDIX A

DRAFT MILITARY SPECIFICATIONS FOR ALTERNATIVE FIREFIGHTER TRAINING AGENT OPE-1

30 Sept 1990

DRAFT MILITARY SPECIFICATION
2,2-DICHLORO-1,1,1-TRIFLUOROETHANE, TECHNICAL*

1.0 SCOPE

1.1 This specification covers the requirements for Ozone Protective Extinguishant No. 1 (OPE-1) for use as a fire extinguishing agent to simulate Halon 1211 for firefighter training.

2.0 APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, documents, and handbooks form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

Federal Specifications:

RR-C-910

-Cylinders, Compressed Gas: DOT 4BA,
DOT 4BW, and DOT 4E

*The following military specification has been reviewed and suggestions were made regarding format and completeness by San Antonio Air Logistics Center, Product Engineering Branch (SA-ALC/SFTT).

PPP-B-601

-Boxes, Wood, Cleated-Plywood.

PPP-B-621

-Boxes, Wood, Nailed and Lock Corner.

PPP-B-636

-Boxes, Shipping, Fiberboard.

FSC 6830

Military Specifications:

MIL-V-2

-Valves, Cylinder, Gas (for
Compressed or Liquefied Gases),
General Specification.

MIL-T-704

-Treatment and Painting of Material.

Federal Standards:

FED. STD. No. H28

-Screw-Thread Standards for Federal
Service.

FED. STD. No. 123

-Marking for Domestic Shipment
(Civil Agencies).

Military Standards:

MIL-STD-101

-Color Code for Pipelines and
for Compressed Gas Cylinders.

MIL-STD-129

-Marking for Shipment and Storage.

MIL-STD-1411

-Inspection and Maintenance of
Compressed Gas Cylinders.

(Copies of specifications, standards, handbooks, drawings, and publications required by manufacturers in connection with specification functions should be obtained from the contracting activity or as directed by the contracting officer.)

(The Code of Federal Regulations [CFR] and the Federal Register [FR], are for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20204-0001. When indicated, reprints of certain regulations may be obtained from the Federal agency responsible for issuance thereof.)

2.1.2 Other Government documents. The following other Government documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issues shall be those cited in the solicitation.

DEPARTMENT OF TRANSPORTATION

49 CFR 171 - 199 - Code of Federal Regulations, Transportation.

(Copies of the Code of Federal Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001.)

(Activities outside the Federal Government may obtain copies of Federal Specifications, standards, regulations, and commercial item descriptions as outlined under General Information in the Index of Federal Specifications and Standards and Commercial Item Descriptions. The index, which includes cumulative bimonthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001.)

(Single copies of this specification and other Federal specifications and commercial item descriptions required by activities outside the Federal Government for bidding purposes are available without charge from General Services Administration

Business Service Centers in Boston, New York, Washington, DC, Atlanta, Chicago, Kansas City, MO, Fort Worth, Houston, Denver, San Francisco, Los Angeles, and Seattle.)

(Federal Government activities may obtain copies of Federal specifications, standards, commercial item descriptions, and the Index of Federal Specifications, Standards and Commercial Item Descriptions from established distribution points in their agencies.)

American Society for Testing and Materials

ASTM D 1209

Color of Clear Liquids
(Platinum-Cobalt Scale)

ASTM D 2108

Color of Halogenated Organic Solvent
and Their Admixtures (Platinum-Cobalt
Scale)

(Application for copies of ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

2.2 Nongovernment standards and other publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 29 - Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.

(Application for copies of ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1107.)

COMPRESSED GAS ASSOCIATION (CGA)

V-1 - American National, Canadian, and Compressed Gas Association Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections.

(Application for copies should be addressed to the Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.)

(Nongovernment standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

3.0 REQUIREMENTS

3.1 Material. The material shall be technically pure grade of 2,2-dichloro-1,1,1-trifluoroethane, suitable as a fire extinguishing fluid for firefighter training and shall conform to the requirements of Table A-1.

TABLE A-1. REQUIREMENTS FOR FIREFIGHTER TRAINING AGENT
OPE-1.

Property	Requirement	Test Par.
2,2-Dichloro-1,1,1-trifluoroethane percent by volume, minimum	99.0	4.4.1
Boiling Point, degrees Celsius at 760 mm Hg	24.0 ± 1 (75.2 ± 1.8 °F)	4.4.2
Water Content, percent by weight, maximum	0.002	4.4.3
Acid Halides & Free Halogens, ppm (by weight), maximum	1.4	4.4.4 and 4.4.5
Nonvolatile Residue, grams/100 mL, maximum	0.02	4.4.6
Suspended Matter or Sediment	None	4.4.7
Color (Platinum-Cobalt Color Standard)	Equal or Less Than #15	4.4.8

3.2 Containers and valves. Unless otherwise specified (6.2) this product shall be contained in the following:

a. Reusable cylinders conforming to specification RR-C-910/1 except that the outlet connection number 668 or 660 of CSA/CGA Standard V-1 shall be used.

b. Disposable cylinders conforming to DOT 39 or 49 CFR 178.

Unless otherwise specified (6.2) reusable cylinders shall be furnished by the Government.

3.3 Container maintenance. Cylinders shall be maintained in accordance with MIL-STD-1411.

3.4 Capacity. Unless otherwise specified (6.2), containers shall be filled to the rated capacity. The weight supplied shall be the difference between the filled weight and the unfilled tank weight of the container (6.3).

3.5 Leakage. Containers and valves shall not leak after being filled.

3.6 Caution Markings. Each container shall be marked to warn personnel to avoid the breathing of vapors. The decal or label shall be placed on the shoulder of the cylinder, but not over identification marking. Labels shall be placed away from outlets on drumheads. A contractor's decal warning against the breathing of vapors is acceptable.

3.7 Limiting values. The following applied to all specified limits in this specification: For purposes of determining conformance with these requirements, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand digit used in expressing the specification limit according to the rounding-off method of ASTM Practice E 29 for using Significant Digits in Test Data to Determine Conformance with Specifications.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified in the contract, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.1.1 Component and Material Inspection. The contractor is responsible for ensuring that components and materials used are manufactured, examined, and tested in accordance with referenced specifications and standards.

4.2 Classification of Inspections. The inspection requirements specified herein are classified as follows:

- (a) Quality conformance inspection (4.3).
- (b) Examination of preparation for delivery (4.5).

4.3 Calibration. Analytical equipment shall be calibrated as applicable in accordance with MIL-STD-45662. Calibration gas standards containing the applicable gaseous components may be required to calibrate the analytical instruments used in test methods. The accuracy of measuring equipment used in preparing these standards shall be traceable to the National Bureau of Standards.

4.4 Test Methods. Unless otherwise specified (6.2) the following tests shall be used.

4.4.1 Assay. The percentage of OPE-1 shall be determined by gas-liquid chromatography. The components of the sample are separated and the area of each peak measured. The OPE-1 content of the sample is found by comparing the area of all the components.

4.4.1.1 Apparatus. The following apparatus is required to determine the percentage of OPE-1:

- a. Gas chromatograph.
- b. Microsyringe, capable of delivering a 2-microliter sample.

4.4.1.2 Reagents. The carrier gas shall be a commercial grade of helium. The column packing shall consist of 20% (wt/wt) practical hexadecane on 30-60 mesh Chromosorb R or equivalent.

4.4.1.3. Operating Conditions.

- a. Column, 12-foot copper tubing 1/4-inch OD, packed with reagent (4.4.1.2).
- b. Column temperature, 40 °C
- c. Helium pressure, 3 lb/in.²
- d. Helium flow rate, 20 cc/minute
- e. Detector voltage, 8 volts
- f. Recorder span, five m.v. full scale

4.4.1.4. Procedure. Prepare the chromatograph for the conditions specified in 4.4.1.3 and allow it to reach equilibrium so that the base line remains on zero at a recorder range setting of 1. Cool at 10 mL Erlenmeyer flask in a one pint Dewar flask, filled with dry ice, and transfer two mL of the sample into it. In a second Dewar flask, place the syringe and cover it with dry ice. Allow syringe to cool for 10 minutes. Set the recorder range on 1 and with the cooled syringe introduce a two-microliter sample into the chromatograph. (The sample size must be chosen so that all peaks stay on scale.) Keep all peaks on scale and run for 20 minutes to record any higher boiling impurities. The chromatogram consists of a series of peaks, following air and carbon dioxide.

4.4.1.5. Calculation. The percent of 2,2-dichloro-1,1,1-trifluoroethane (CF_3CHCl_2) shall be calculated as follows:

$$\% \text{CF}_3\text{CHCl}_2 = \frac{A(\text{CF}_3\text{CHCl}_2)}{A_s} \times 100$$

Where:

$A(\text{CF}_3\text{CHCl}_2)$ = area (in sq. cm) of 2,2-dichloro-1,1,1-trifluoroethane multiplied by recorder range setting

A_s = sum of the peak areas

4.4.2 Boiling point, boiling range, and high boiling impurities (nonvolatile residue).

4.4.2.1 Apparatus.

- (a) Goetz phosphorus tube, 100 mL capacity.
- (b) Thermometer, National Bureau of Standards certified for the temperature range anticipated.

- (c) Barometer accurate to $\pm 0.5\%$.
- (d) Carborundum crystals, 20 mesh.

4.4.2.2 Procedure.

- (a) Fill the Goetz tube with 100 mL of the sample, add two or three crystals of carborundum, and suspend temperature indicating instrument in the sample.
- (b) Suspend the tube in a medium (air or water) held at a minimum temperature of 50 °C (90 °F) above the expected boiling point.
- (c) As soon as the thermometer is constant after 5 mL of the sample have been distilled, record the reading as the initial observed boiling point.
- (d) Record as the end point the temperature reached when 85 mL of sample have evaporated. Calculate the boiling range.
- (e) Transfer the tube and the remaining 15 mL of sample to a second medium maintained at a temperature 28 °C (50 °F) above the boiling point.
- (f) After 30 minutes, record the residual material as the percentage of high boiling impurities (nonvolatile residue).
- (g) Correct the observed boiling point to the boiling point at 760 mm Hg as follows:

$$\text{B.P.}^{\circ}\text{C} = \text{Obs. B.P.}^{\circ}\text{C} + 0.00012(760 - \text{Obs. Bar. Pressure})(273 + \text{Obs. B.P.}^{\circ}\text{C})$$

4.4.3 Water content. OPE-1 shall be tested for water (moisture) content. The analysis may be conducted by using the phosphorus pentoxide method, by infrared absorption, by an electrolytic moisture analyzer, or by a piezoelectric analyzer. The Karl Fischer method of ASTM E 700 shall be the referee method in confirming accuracy of results.

4.4.4 Acid Halides. A large sample shall be evaporated in the presence of a small amount of crushed ice - distilled water slurry. The solution is titrated for acid halides with standardized sodium hydroxide.

4.4.4.1 Reagents.

a. Sodium hydroxide, 0.01N solution: Dissolve 0.40 grams of carbonate-free sodium hydroxide in recently boiled distilled water in a 1000 mL volumetric flask. Cool and dilute to the mark. This solution shall be standardized against reagent grade potassium acid phthalate.

b. Methyl red indicator, 0.1% solution.

4.4.4.2 Procedure Place 10 mL of a crushed ice - distilled water slurry in a 250 mL glass stoppered Erlenmeyer flask, and add 50 grams of OPE-1 to the slurry. Place the stopper in the flask loosely, and swirl the flask gently from time to time until the ice is completely melted. Add one drop of methyl red indicator and if a reddish color remains, titrate to a yellow endpoint with 0.01N sodium hydroxide solution.

CAUTION - Perform the above procedure in a hood.

4.4.4.3 Calculation. The ppm acid halides, as HCl, shall be calculated as follows:

$$\text{ppm Acid Halides (as HCl)} = \frac{\text{mL NaOH} \times \text{N NaOH} \times 0.0365 \times 10^6}{\text{weight of sample (grams)}}$$

4.4.5 Free Halogen. The free halogen shall be treated with an excess of potassium iodide and the iodide liberated is titrated with sodium thiosulfate solution.

4.4.5.1 Reagents

a. Sodium thiosulfate, 0.01N solution: Prepare a 0.1N solution by dissolving 25 grams of sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) and 0.5 grams of sodium carbonate in one liter of distilled water. Standardize against 0.1N potassium dichromate solution.

From this 0.1N solution of sodium thiosulfate, prepare a 0.01N solution: Pipet a 10 mL aliquot of the standard 0.1N sodium thiosulfate solution into a 100 mL volumetric flask, fill to the mark with distilled water and mix. Prepare the 0.01N sodium thiosulfate solution fresh daily.

- b. Sulfuric acid, 1:4 solution in water.
- c. Potassium iodide, 10 percent solution in water.
- d. Starch indicator.

4.4.5.2 Procedure. Pour 100 mL of 10 percent potassium iodide solution into a 250 mL Erlenmeyer flask, add 10 mL 1:4 sulfuric acid and 1 mL of starch solution. Bubble 100 grams of OPE-1 vapor through the potassium iodide solution. Titrate any liberated iodine with standard 0.01N sodium thiosulfate solution. Run a reagent blank along with the sample.

4.4.5.3 Calculation. The ppm of free halogen, as chlorine, shall be calculated as follows:

$$\text{ppm Free Halogen (as Cl)} = \frac{(A - B) \times N \text{ Na}_2\text{S}_2\text{O}_3 \times 0.0355 \times 10^6}{\text{weight of sample in grams}}$$

Where

A = Volume $\text{Na}_2\text{S}_2\text{O}_3$ solution (mL) required to titrate sample

B = Volume $\text{Na}_2\text{S}_2\text{O}_3$ solution (mL) required to titrate blank

4.4.6 Nonvolatile Residue. One hundred mL of OPE-1 shall be evaporated and the residue weighed.

4.4.6.1 Procedure. Add 100 mL of OPE-1 to a weighed evaporating dish. Allow the sample to evaporate to dryness in a hood. After evaporation is complete, dry for 15 minutes in a drying oven at 105 °C. Cool the evaporating dish in a desiccator and reweigh. The gain in weight (residue) is expressed in grams per 100 mL.

4.4.7 Suspended Matter and Sediment. Examine visually for any suspended matter or sediment.

4.4.8 Color. A sample of OPE-1 shall be compared with color standards (ASTM D 1209 or D 2108).

4.4.8.1 Reagents.

a. Platinum-Cobalt Stock Solution. Dissolve 1.245 grams of potassium chloroplatinate (K_2PtCl_6) and 1.000 grams of cobaltous chloride ($CoCl_2 \cdot 6H_2O$) in water. Add 100 mL of concentrated hydrochloric acid and dilute to 1 liter with water. This solution has a color of 500.

b. Platinum-Cobalt Standards. Prepare color standards having a color of 5, 10, 15 by diluting 1.0, 2.0, and 3.0 mL of above solution in Nessler tubes to 100 mL with water.

4.4.8.2 Procedure. Pour the sample into a cold, clean, dry Nessler tube and compare with the standard by looking straight down through the Nessler tube against a white background. The number of the standard that most nearly matches the sample is reported as the color.

4.4.9 Chloride ion test. Add 3 or 4 drops of a saturated solution of silver nitrate to 5 mL of absolute methyl alcohol in a test tube and shake. The reagent blank shall be

negative. Add 5 mL of the sample. Any turbidity indicates the presence of chloride ions and constitutes failure of this test.

5.0 PREPARATION FOR DELIVERY

5.1 Packing. Packing shall be level A, B, or Commercial, as specified (6.2).

5.1.1 Containers and Valves. Unless otherwise specified herein, the firefighter training agent OPE-1 shall be contained in Government-furnished cylinders in accordance with CFR Title 49, 171-190, and equipped with valves in accordance with MIL-V-2/22 with outlet connection No. 668 or 660 in accordance with FED-STD-H28. When specified (6.2), cylinders shall be furnished by the contractor in accordance with RR-C-910 and shall be equipped with valves in accordance with MIL-V-2. When specified (6.2), the firefighter training agent OPE-1 shall be contained in contractor-owned DOT-approved containers with valves with outlet connection No. 668.

5.1.1.1 Disposable Containers. When specified (6.2), the contractor shall furnish disposable containers of the capacity as specified in accordance with the CFR Title 49, Specification 39. The unit of pack for disposable containers requires packaging in fiberboard boxes in accordance with Specification 39, and marking (5.2) shall be in high visibility on each unit of pack. Drums of 100-200 pounds conforming to Specification 17E shall be used.

5.1.1.2 Cylinders. Unless otherwise specified, cylinders shall be palletized in accordance with MIL-STD-147. The loads shall be secured in accordance with the appendix to the applicable specification.

5.1.2 Commercial. OPE-1 containers shall be packed in accordance with Title 49 Code of Federal Regulations.

5.2 Marking.

5.2.1 Military agencies. In addition to any special marking required by the contract or order, marking for level A or B shall be in accordance with MIL-STD-129. Filled cylinders shall be color coded in accordance with MIL-STD-101.

5.2.2 Civil agencies. Marking shall be in accordance with FED. STD. No. 123.

6.0 NOTES

6.1 Intended Use. The OPE-1 firefighter training agent covered by this specification is intended only for use in firefighter training under controlled conditions by professional personnel following applicable safety precautions including use of self-contained breathing apparatus (SCBA).

6.2 Ordering data. Purchasers should select the preferred options permitted herein and include the following information in procurement documents:

- (a) Title, number, and date of this specification.
- (b) Quantity of OPE-1 desired.
- (c) Type and size of container required.
- (d) When contractor shall furnish Government-approved cylinders (3.2).
- (e) When contractor-owned DOT-approved cylinders shall be furnished (3.2).
- (f) When military material painting is required.
- (g) When cylinder capacities shall differ from capacities of Government-approved cylinders (3.4).
- (h) Cylinder valve type.
- (i) Level of packing required (5.1).
- (j) When containers shall be boxed, palletized, or shipped loose (5.1.1.2).

6.3 Automated cylinder handling systems. Fluorocarbon chemicals similar to OPE-1 have been purchased for a number of years on a cost per unit basis. Suppliers of fluorocarbons operate near automated filling plants in which valves, cylinders, and containers are serviced internally and externally in accordance with the requirements of Title 49 Code of Federal Regulations, to maintain the purity and integrity of the suppliers' fluorocarbon products. In these contracts Government cylinders are received, serviced (including color coding, MIL-STD-101), and filled, or rejected and returned to the supplying agency at no additional charge for cylinder service. This specification has been written to accept automatic internal and external cylinder handling unless otherwise specified for special military requirements.

6.4 Purity. The percentage of 2,2-dichloro-1,1,1-trifluoroethane in OPE-1 may be determined as specified herein or by a method acceptable to the procuring agency.

6.5 Recycled material. It is encouraged that recycled material be used when practical as long as it meets the requirements of the specification.

MILITARY INTERESTS:

Custodians:

Air Force - 68

Navy - SH

Army- ME

Review activities:

Air Force - 68

Army - MD, EA, MI

DSA - GS

User activity:

Air Force - 68

Navy - YD

DOD - NA

CIVIL AGENCY COORDINATING ACTIVITIES:

GSA - FSS

HEW - FDA

VA - OSS

Preparing activity:

Air Force - 68

APPENDIX B

DRAFT MILITARY SPECIFICATIONS FOR ALTERNATIVE FIREFIGHTER TRAINING AGENT OPE-2

30 Sept 1990

DRAFT MILITARY SPECIFICATION
OZONE PROTECTIVE EXTINGUISHANT (OPE) NUMBER TWO
(80:20 BLEND BY MOLES OF 2,2-DICHLORO-1,1,1-TRIFLUOROETHANE AND
1-CHLORO-1,1-DIFLUOROETHANE, BOTH TECHNICAL GRADES)**

1.0 SCOPE

1.1 This specification covers the requirements for Ozone Protective Extinguishant No. 2 (OPE-2) for use as a fire extinguishing agent to simulate Halon 1211 for firefighter training.

2.0 APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, documents, and handbooks form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

***The following military specification has been reviewed and suggestions were made regarding format and completeness by San Antonio Air Logistics Center, Product Engineering Branch (SA-ALC/SFTT).

Federal Specifications:

RR-C-910	-Cylinders, Compressed Gas: DOT 4BA, DOT 4BW, and DOT 4E
PPP-B-601	-Boxes, Wood, Cleated-Plywood.
PPP-B-621	-Boxes, Wood, Nailed and Lock Corner.
PPP-B-636	-Boxes, Shipping, Fiberboard.

FSC 6830

Military Specifications:

MIL-V-2	-Valves, Cylinder, Gas (for Compressed or Liquefied Gases), General Specification.
MIL-T-704	-Treatment and Painting of Material.

Federal Standards:

FED. STD. No. H28	-Screw-Thread Standards for Federal Service.
FED. STD. No. 123	-Marking for Domestic Shipment (Civil Agencies).

Military Standards:

MIL-STD-101	-Color Code for Pipelines and for Compressed Gas Cylinders.
MIL-STD-129	-Marking for Shipment and Storage.

(Copies of specifications, standards, handbooks, drawings, and publications required by manufacturers in connection with specification functions should be obtained from the contracting activity or as directed by the contracting officer.)

(The Code of Federal Regulations [CFR] and the Federal Register [FR], are for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20204-0001. When indicated, reprints of certain regulations may be obtained from the Federal agency responsible for issuance thereof.)

2.1.2 Other Government documents. The following other Government documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issues shall be those cited in the solicitation.

DEPARTMENT OF TRANSPORTATION

49 CFR 171 - 199 - Code of Federal Regulations, Transportation.

(Copies of the Code of Federal Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001.)

(Activities outside the Federal Government may obtain copies of Federal Specifications, standards, regulations, and commercial item descriptions as outlined under General Information in the Index of Federal Specifications and Standards and Commercial Item Descriptions. The index, which includes cumulative bimonthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001.)

(Single copies of this specification and other Federal specifications and commercial item descriptions required by activities outside the Federal Government for bidding purposes are available without charge from General Services Administration Business Service Centers in Boston, New York, Washington, DC, Atlanta, Chicago, Kansas City, MO, Fort Worth, Houston, Denver, San Francisco, Los Angeles, and Seattle.)

(Federal Government activities may obtain copies of Federal specifications, standards, commercial item descriptions, and the Index of Federal Specifications, Standards and Commercial Item Descriptions from established distribution points in their agencies.)

American Society for Testing and Materials

ASTM D 1209

Color of Clear Liquids
(Platinum-Cobalt Scale)

ASTM D 2108

Color of Halogenated Organic Solvent
and Their Admixtures (Platinum-Cobalt
Scale)

(Application for copies of ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

2.2 Nongovernment standards and other publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 29 - Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.

(Application for copies of ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

COMPRESSED GAS ASSOCIATION (CGA)

V-1 - American National, Canadian, and Compressed Gas Association Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections.

(Application for copies should be addressed to the Compressed Gas Association, Inc, 1235 Jefferson Davis Highway, Arlington VA 22202.)

(Nongovernment standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

3.0 REQUIREMENTS

3.1 Material. The material shall be an 80:20 blend by moles of technically pure grade of 2,2-dichloro-1,1,1-trifluoroethane and technically pure 1-chloro-1,1-difluoroethane, suitable as a fire extinguishing fluid for firefighter training and shall conform to the requirements of Table B-1.

**TABLE B-1. REQUIREMENTS FOR FIREFIGHTER TRAINING AGENT
OPE-2.**

Property	Requirement	Test Par.
2,2-Dichloro-1,1,1-trifluoroethane percent by moles	80.0 ± 1	4.4.1
1-Chloro-1,1-difluoroethane percent by moles	20.0 ± 1	4.4.1
Boiling Point, degrees Celsius at 760 mm Hg	-10 to +28 (14 to 82 °F)	4.4.2
Water Content, percent by weight, maximum	0.002	4.4.3
Acid Halides & Free Halogens, ppm (by weight), maximum	1.4	4.4.4 and 4.4.5
Nonvolatile Residue, grams/100 mL, maximum	0.02	4.4.6
Suspended Matter or Sediment	None	4.4.7
Color (Platinum-Cobalt Color Standard)	Equal or Less Than #15	4.4.8

3.2 Containers and valves. Unless otherwise specified (6.2) this product shall be contained in the following:

a. Reusable cylinders conforming to specification RR-C-910/1 except that the outlet connection number 668 or 660 of CSA/CGA Standard V-1 shall be used.

b. Disposable cylinders conforming to DOT 39 or 49 CFR 178.

Unless otherwise specified (6.2) reusable cylinders shall be furnished by the Government.

3.3 Container maintenance. Cylinders shall be maintained in accordance with MIL-STD-1411.

3.4 Capacity. Unless otherwise specified (6.2), containers shall be filled to the rated capacity. The weight supplied shall be the difference between the filled weight and the unfilled tank weight of the container (6.3).

3.5 Leakage. Containers and valves shall not leak after being filled.

3.6 Caution Markings. Each container shall be marked to warn personnel to avoid the breathing of vapors. The decal or label shall be placed on the shoulder of the cylinder, but not over identification marking. Labels shall be placed away from outlets on drumheads. A contractor's decal warning against the breathing of vapors is acceptable.

3.7 Limiting values. The following applied to all specified limits in this specification: For purposes of determining conformance with these requirements, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand digit used in expressing the specification limit according to the rounding-off method of ASTM Practice E 29 for using Significant Digits in Test Data to Determine Conformance with Specifications.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified in the contract, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.1.1 Component and Material Inspection. The contractor is responsible for ensuring that components and materials used are manufactured, examined, and tested in accordance with referenced specifications and standards.

4.2 Classification of Inspections. The inspection requirements specified herein are classified as follows:

- (a) Quality conformance inspection (4.3).
- (b) Examination of preparation for delivery (4.5).

4.3 Calibration. Analytical equipment shall be calibrated as applicable in accordance with MIL-STD-45662. Calibration gas standards containing the applicable gaseous components may be required to calibrate the analytical instruments used in test methods. The accuracy of measuring equipment used in preparing these standards shall be traceable to the National Bureau of Standards.

4.4 Test Methods. Unless otherwise specified (6.2) the following tests shall be used.

4.4.1 Assay. The percentage of OPE-2 shall be determined by gas-liquid chromatography. The components of the sample are separated and the area of each peak measured. The OPE-2 content of the sample is found by comparing the area of all the components.

4.4.1.1 Apparatus. The following apparatus is required to determine the percentage of OPE-2:

- a. Gas chromatograph.
- b. Microsyringe, capable of delivering a 2-microliter sample.

4.4.1.2 Reagents. The carrier gas shall be a commercial grade of helium. The column packing shall consist of 20% (wt/wt) practical hexadecane on 30-60 mesh Chromosorb R or equivalent.

4.4.1.3. Operating Conditions.

- a. Column, 12-foot copper tubing 1/4-inch OD, packed with reagent (4.4.1.2).
- b. Column temperature, 40 °C
- c. Helium pressure, 3 lb/in.²
- d. Helium flow rate, 20 cc/minute
- e. Detector voltage, 8 volts
- f. Recorder span, five m.v. full scale

4.4.1.4. Procedure. Prepare the chromatograph for the conditions specified in 4.4.1.3 and allow it to reach equilibrium so that the base line remains on zero at a recorder range setting of 1. Cool at 10 mL Erlenmeyer flask in a one pint Dewar flask, filled with dry ice, and transfer two mL of the sample into it. In a second Dewar flask, place the syringe and cover it with dry ice. Allow syringe to cool for 10 minutes. Set the recorder range on 1 and with the cooled syringe introduce a two-microliter sample into the chromatograph. (The sample size must be chosen so that all peaks stay on scale.) Keep all peaks on scale and run for 20 minutes to record any higher boiling impurities. The chromatogram consists of a series of peaks, following air and carbon dioxide.

4.4.1.5. Calculation. The percent of 2,2-dichloro-1,1,1-trifluoroethane (CF_3CHCl_2) shall be calculated as follows:

$$\% \text{CF}_3\text{CHCl}_2 = \frac{A(\text{CF}_3\text{CHCl}_2)}{A_s} \times 100$$

Where

$A(\text{CF}_3\text{CHCl}_2)$ = area (in sq. cm) of 2,2-dichloro-1,1,1-trifluoroethane multiplied by recorder range setting and the detector molar response factor.

A_s = sum of the peak areas multiplied by detector molar response factors.

The percent of 1-chloro-1,1-difluoroethane (CClF_2CH_3) shall be calculated as follows:

$$\% \text{CClF}_2\text{CH}_3 = \frac{A(\text{CClF}_2\text{CH}_3)}{A_s} \times 100$$

Where

$A(\text{CClF}_2\text{CH}_3)$ = Area (in sq. cm) of 1-chloro-1,1-difluoroethane multiplied by recorder range setting and the detector molar response factor.

A_s = sum of the peak areas multiplied by detector molar response factors.

4.4.2 Boiling point, boiling range, and high boiling impurities (nonvolatile residue).

4.4.2.1 Apparatus.

- (a) Goetz phosphorus tube, 100 mL capacity.
- (b) Thermometer, National Bureau of Standards certified for the temperature range anticipated.
- (c) Barometer accurate to $\pm 0.5\%$.
- (d) Carborundum crystals, 20 mesh.

4.4.2.2 Procedure.

- (a) Fill the Goetz tube with 100 mL of the sample, add two or three crystals of carborundum, and suspend temperature indicating instrument in the sample.
- (b) Suspend the tube in a medium (air or water) held at a minimum temperature of 50°C (90°F) above the expected boiling point.
- (c) As soon as the thermometer is constant after 5 mL of the sample has been distilled, record the reading as the initial observed boiling point.
- (d) Record as the end point the temperature reached when 85 mL of sample has evaporated. Calculate the boiling range.
- (e) Transfer the tube and the remaining 15 mL of sample to a second medium maintained at a temperature 28°C (50°F) above the boiling point.

- (f) After 30 minutes, record the residual material as the percentage of high boiling impurities (nonvolatile residue).
- (g) Correct the observed boiling point to the boiling point at 760 mm Hg as follows:

$$\text{B.P.}^{\circ}\text{C} = \text{Obs. B.P.}^{\circ}\text{C} + 0.00012(760 - \text{Obs. Bar. Pressure})(273 + \text{Obs. B.P.}^{\circ}\text{C})$$

4.4.3 Water content. OPE-2 shall be tested for water (moisture) content. The analysis may be conducted by using the phosphorus pentoxide method, by infrared absorption, by an electrolytic moisture analyzer, or by a piezoelectric analyzer. The Karl Fischer method of ASTM E 700 shall be the referee method in confirming accuracy of results.

4.4.4 Acid Halides. A large sample shall be evaporated in the presence of a small amount of crushed ice - distilled water slurry. The solution is titrated for acid halides with standardized sodium hydroxide.

4.4.4.1 Reagents.

a. Sodium hydroxide, 0.01N solution: Dissolve 0.40 grams of carbonate-free sodium hydroxide in recently boiled distilled water in a 1000 mL volumetric flask. Cool and dilute to the mark. This solution shall be standardized against reagent grade potassium acid phthalate.

b. Methyl red indicator, 0.1% solution.

4.4.4.2 Procedure. Place 10 mL of a crushed ice-distilled water slurry in a 250 mL glass stoppered Erlenmeyer flask, and add 50 grams of OPE-2 to the slurry. Place the stopper in the flask loosely, and swirl the flask gently from time to time until the ice is completely melted. Add one drop of methyl red indicator and if a reddish color remains, titrate to a yellow endpoint with 0.01N sodium hydroxide solution.

CAUTION - Perform the above procedure in a hood.

4.4.4.3 Calculation. The ppm acid halides, as HCl, shall be calculated as follows:

$$\text{ppm Acid Halides (as HCl)} = \frac{\text{mL NaOH} \times \text{N NaOH} \times 0.0365 \times 10^6}{\text{weight of sample (grams)}}$$

4.4.5 Free Halogen. The free halogen shall be treated with an excess of potassium iodide and the iodide liberated is titrated with sodium thiosulfate solution.

4.4.5.1 Reagents

a. Sodium thiosulfate, 0.01N solution: Prepare a 0.1N solution by dissolving 25 grams of sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) and 0.5 grams of sodium carbonate in one liter of distilled water. Standardize against 0.1N potassium dichromate solution. From this 0.1N solution of sodium thiosulfate, prepare a 0.01N solution: Pipet a 10 mL aliquot of the standard 0.1N sodium thiosulfate solution into a 100 mL volumetric flask, fill to the mark with distilled water and mix. Prepare the 0.01N sodium thiosulfate solution fresh daily.

b. Sulfuric acid, 1:4 solution in water.

c. Potassium iodide, 10 percent solution in water.

d. Starch indicator.

4.4.5.2 Procedure. Pour 100 mL of 10 percent potassium iodide solution into a 250 mL Erlenmeyer flask, add 10 mL 1:4 sulfuric acid and 1 mL of starch solution. Bubble 100 grams of OPE-2 vapor through the potassium iodide solution. Titrate any liberated

iodine with standard 0.01N sodium thiosulfate solution. Run a reagent blank along with the sample.

4.4.5.3 Calculation. The ppm of free halogen, as chlorine, shall be calculated as follows:

$$\text{ppm Free Halogen (as Cl)} = \frac{(A - B) \times N \text{ Na}_2\text{S}_2\text{O}_3 \times 0.0355 \times 10^6}{\text{weight of sample in grams}}$$

Where

A = Volume $\text{Na}_2\text{S}_2\text{O}_3$ solution (mL) required to titrate sample

B = Volume $\text{Na}_2\text{S}_2\text{O}_3$ solution (mL) required to titrate blank

4.4.6 Nonvolatile Residue. One hundred mL of OPE-2 shall be evaporated and the residue weighed.

4.4.6.1 Procedure. Add 100 mL of OPE-2 to a weighed evaporating dish. Allow the sample to evaporate to dryness in a hood. After evaporation is complete, dry for 15 minutes in a drying oven at 105 °C. Cool the evaporating dish in a desiccator and reweigh. The gain in weight (residue) is expressed in grams per 100 mL.

4.4.7 Suspended Matter and Sediment. Examine visually for any suspended matter or sediment.

4.4.8 Color. A sample of OPE-2 shall be compared with color standards (ASTM D 1209 or D 2108).

4.4.8.1 Reagents.

a. Platinum-Cobalt Stock Solution. Dissolve 1.245 grams of potassium chloroplatinate (K_2PtCl_6) and 1.000 grams of cobaltous chloride ($CoCl_2 \cdot 6H_2O$) in water. Add 100 mL of concentrated hydrochloric acid and dilute to 1 liter with water. This solution has a color of 500.

b. Platinum-Cobalt Standards. Prepare color standards having a color of 5, 10, 15 by diluting 1.0, 2.0 and 3.0 mL of above solution in Nessler tubes to 100 mL with water.

4.4.8.2 Procedure. Pour the sample into a cold, clean, dry Nessler tube and compare with the standard by looking straight down through the Nessler tube against a white background. The number of the standard that most nearly matches the sample is reported as the color.

4.4.9 Chloride ion test. Add 3 or 4 drops of a saturated solution of silver nitrate to 5 mL of absolute methyl alcohol in a test tube and shake. Reagent blank shall be negative. Add 5 mL of the sample. Any turbidity indicates the presence of chloride ions and constitutes failure of this test.

5.0 PREPARATION FOR DELIVERY

5.1 Packing. Packing shall be level A, B, or Commercial, as specified (6.2).

5.1.1 Containers and Valves. Unless otherwise specified herein, the firefighter training agent OPE-2 shall be contained in Government-furnished cylinders in accordance with CFR Title 49, 171-190, and equipped with valves in accordance with MIL-V-2/22 with outlet connection No. 668 or 660 in accordance with FED-STD-H28. When specified

(6.2), cylinders shall be furnished by the contractor and shall be in accordance with RR-C-910 and shall be equipped with valves in accordance with MIL-V-2. When specified (6.2), the firefighter training agent OPE-2 shall be contained in contractor-owned DOT-approved containers with valves with outlet connection No. 668.

5.1.1.1 Disposable Containers. When specified (6.2), the contractor shall furnish disposable containers of the capacity as specified in accordance with the CFR Title 49, Specification 39. The unit of pack for disposable containers requires packaging in fiberboard boxes in accordance with Specification 39, and marking (5.2) shall be in high visibility on each unit of pack. Drums of 100-200 pounds conforming to Specification 17E shall be used.

5.1.1.2 Cylinders. Unless otherwise specified, cylinders shall be palletized in accordance with MIL-STD-147. The loads shall be secured in accordance with the appendix to the applicable specification.

5.1.2 Commercial. OPE-2 containers shall be packed in accordance with Title 49 Code of Federal Regulations.

5.2 Marking.

5.2.1 Military agencies. In addition to any special marking required by the contract or order, marking for level A or B shall be in accordance with MIL-STD-129. Filled cylinders shall be color coded in accordance with MIL-STD-101.

5.2.2 Civil agencies. Marking shall be in accordance with FED. STD. No. 123.

6.0 NOTES

6.1 Intended Use. The OPE-2 firefighter training agent covered by this specification is intended only for use in firefighter training under controlled conditions by professional personnel following applicable safety precautions including use of self-contained breathing apparatus (SCBA).

6.2 Ordering data. Purchasers should select the preferred options permitted herein and include the following information in procurement documents:

- (a) Title, number, and date of this specification.
- (b) Quantity of OPE-2 desired.
- (c) Type and size of container required.
- (d) When contractor shall furnish Government-approved cylinders (3.2).
- (e) When contractor-owned DOT-approved cylinders shall be furnished (3.2).
- (f) When military material painting is required.
- (g) When cylinder capacities shall differ from capacities of Government-approved cylinders (3.4).
- (h) Cylinder valve type.
- (i) Level of packing required (5.1).
- (j) When containers shall be boxed, palletized, or shipped loose (5.1.1.2).

6.3 Automated cylinder handling systems. Fluorocarbon chemicals similar to OPE-2 have been purchased for a number of years on a cost per unit basis. Suppliers of fluorocarbons operate near automated filling plants in which valves, cylinders, and containers are serviced internally and externally in accordance with the requirements of Title 49 Code of Federal Regulations, to maintain the purity and integrity of the suppliers' fluorocarbon products. In these contracts Government cylinders are received, serviced (including color coding, MIL-STD-101), and filled, or rejected and returned to the supplying agency at no additional charge for cylinder service. This specification has

been written to accept automatic internal and external cylinder handling unless otherwise specified for special military requirements.

6.4 Purity. The percentage of 2,2-dichloro-1,1,1-trifluoroethane in OPE-2 may be determined as specified herein or by a method acceptable to the procuring agency.

6.5 Recycled material. It is encouraged that recycled material be used when practical as long as it meets the requirements of the specification.

MILITARY INTERESTS:

CIVIL AGENCY COORDINATING ACTIVITIES.

Custodians:

Air Force - 68

Navy - SH

Army- ME

GSA - FSS

HEW - FDA

VA - OSS

Review activities:

Air Force - 68

Army - MD, EA, MI

DSA - GS

Preparing activity:

Air Force - 68

User activity:

Air Force - 68

Navy - YD

DOD - NA